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VALIDATION OF TWO AIRCREW PSYCHOMOTOR TESTS

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Brooks Air Force Base, Texas

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study documents the initial validation of two psychomotor tests developed by the Air Force Human Resources Laboratory. The tests, known as Two-Hand Coordination and Complex Coordination, bear the names of two devices used in aircrew selection in World War II, but the new tests do not closely resemble the old. The new tests use equipment which takes advantage of solid-state electronics and a mini-computer. These tests were validated on a sample of 121 student officers scheduled for pilot training. Criteria were graduation from pilot training and attrition by reason of flying deficiency. Multiple regression analyses supported the conclusion that the two psychomotor tests together make a significant contribution to prediction of graduation in the context of the Air Force Officer Qualifying Test. Correlation data suggested that Complex Coordination is the more effective of the

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psychomotor tests when taken singly. A second validation study, using a similarly defined sample of 92 subjects, was focused only on Complex Coordination. Scores on this test contributed significantly to the prediction of graduation in the context of the Air Force Officer Qualifying Test. In the same context, Complex Coordination contributed significantly to prediction of a criterion category containing flying deficiency eliminees and self initiated eliminees. It is concluded that the psychomotor tests, especially Complex Coordination, are effective in predicting performance in undergraduate pilot training. It is recommended that an operational version of the tests and equipment be developed and used in a large scale validation study.

PREFACE

This research was performed under Project 7719, Air Force Personnel System Development on Selection, Assignment, Evaluation, Quality Control, Retention, Promotion, and Utilization; Task 771915, Development of Perceptual-Psychomotor Measures for Air Force Enlisted Programs. Certain refinements in the manuscript were accomplished by Robert E. Miller.

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I. INTRODUCTION

This report presents initial findings on the utility of two psychomotor tests for improved selection of Air Force pilots. During World War II, and for several years thereafter, an extensive program of psychomotor research was conducted by the Army Air Forces Psychological Research Unit No. 2 and the School of Aviation Medicine (now the School of Aerospace Medicine). Selected psychomotor tests developed under this program were an intergral part of the World War II aircrew classification batteries. This early effort has been described by Melton (1947). Generally, it was found that psychomotor assessments had validity for predicting elimination from pilot training beyond that obtained from paper-and-pencil tests. Use of psychomotor assessments in the Air Force pilot selection program was discontinued in the early 1950s because of the expense and difficulty of maintaining and calibrating the required equipment under decentralized testing conditions.

With recent technological advances, there has been a revival of interest in the utility of psychomotor assessments both for selection of pilot trainees and for a variety of other personnel decisions. In one study sponsored by the Air Force, Passey and McLaurin (1966) conducted an extensive review of work in the perceptual-psychomotor area and provided tentative design requirements for updated psychomotor equipment and tests.

The Air Force recently completed an extensive *Mission Analysis on Future Undergraduate Pilot Training: 1975 through 1990* (1972). This included consideration of selection devices and procedures most likely to meet the needs of the force over approximately the next twenty years. In anticipation of such future needs, planning for development of a psychomotor research capability began in 1969 and progressed in 1970 to the establishment of a prototype psychomotor research facility at the Personnel Research Division, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. It was intended from the beginning that this facility take advantage of technological advances using solid-state components and mini-computers in place of the somewhat unreliable systems of the World War II era. The resulting system is characterized by ease of modification, simple programming to accommodate a variety of experimental tests, and a capacity for easy expansion to include additional subject test stations.

This study reports validation of the first tests to be programmed on this equipment. These are known as two-hand coordination and complex coordination. Two of the psychomotor tests which demonstrated good validity for pilot selection in World War II carried these same names, but the current tests were modeled after them only in the sense that they require somewhat the same response capability of the subject. It was deemed neither necessary nor desirable to reproduce the older tests exactly. The design of the equipment and the development of the current tests have been described in detail by Sanders, Valentine, and McGrevy (1971).

II. VALIDATION STUDY I

Subjects

As the final phase of the development of the psychomotor equipment, 148 Air Force officer trainees were administered the Two-Hand Coordination and Complex Coordination tests. Of these subjects, 121 graduated from the School of Military Science-Officer and entered undergraduate pilot training (UPT). All had previously taken the Air Force Officer Qualifying Test (AFOQT).

The Tests

Two-Hand coordination requires manipulation of joysticks, one in each hand, to control the position of an X-shaped stimulus on a screen. Instructions to the subject require that he maintain the position of the X as close as he can to a triangular target, which moves in a circular path at varying speeds. At any given moment, a deviation of the X from the target constitutes an error which is measurable both in terms of the horizontal and vertical displacement. The smallest measurable error is about .01 inches. These error measurements on two axes, when integrated separately by the mini-computer over a specified time interval, constitute the basic scores obtained from this test. A Generated score, equal to the square root of the sum of squares of the two error scores, is also obtained.

Complex Coordination requires manipulation of a single joystick to control the movement of an

X-shaped stimulus, while at the same time using both feet to control a short vertical line which hovers near the bottom of the screen. The instructions require that both the X and the short line be held stationary at points on the screen identified by fixed intersecting lines. Error scores on the manipulation of the X stimulus are integrated over time along two axes separately, and a Generated score, defined as in Two-Hand Coordination, is also obtained. The score for manipulation of the vertical line is the integrated horizontal displacement from the fixed intersection over time. In addition, there is a Reset score which expresses the frequency per time interval that the subject allows the short line to leave the screen. When this occurs, the line is returned automatically.

The Predictors

For Two-Hand Coordination, the predictors were the integrated horizontal and vertical error scores, known respectively as X Axis and Y Axis scores. The Generated score was also used. For Complex Coordination, the predictors were X Axis, Y Axis, and Generated scores, and the integrated error score for the vertical line. This is known as the Z Axis sc . . Finally, the Reset score was used as a predictor.

Raw subtest scores on the AFOQT constituted another set of predictors. This test is currently used in several operational programs, including the selection of student pilots. A proper validation of the psychomotor tests must, therefore, demonstrate that they significantly improve this existing selection system. Most AFOQT subtest scores are not routinely computed, but special arrangements were made to obtain them as part of the final phase of the psychomotor test development. Subtests not normally involved in pilot selection were included.

The Criteria

Criterion data in the form of graduation or attrition status from UPT were obtained for each subject during December 1971 and January 1972. Table 1 presents the criterion distribution of the subjects. The specific criteria used in the study were Graduation and Flying Training Deficiency (FTD) elimination. To permit numerical analysis, each criterion variable was coded 1 for subjects falling in that criterion group and zero for all others.

Table 1. **Distribution of Subjects by Criterion Category, Validation Study I**

Category	N
Flying Training Deficiency Elimination (FTD)	19
Self Initiated Elimination (SIE)	9
Manifestation of Apprehension Elimination	2
Medical Elimination	4
Total Elimination	34
Total Graduation	87
Total Subjects	121

Test Procedure

All testing was done in December 1970. The subjects were first administered Two-Hand Coordination, followed one minute later by Complex Coordination. Each test involved four minutes of standardized instructions and practice, of which three minutes were for practice. Following the practice period, a five minute test session was conducted. For each test, the error scores were integrated over five observation periods of one minute each. Thus, five values were available on each psychomotor predictor for each subject.

Results

When the data were analyzed, it became apparent that a programming difficulty had invalidated all Z Axis scores. Other scores were unaffected, and the analysis was performed in terms of them.

To provide a better characterization of the sample and to facilitate interpretation of the findings, the mean AFOQT composite scores in percentile form were computed. These were found to be as follows: Pilot 80, Navigator-Technical 70, Officer Quality 70, Verbal 45, and Quantitative 50. The very high Pilot mean indicates a fairly severe restriction in the range of Pilot scores. As a consequence, AFOQT Pilot validities are underestimates of their values in the unrestricted population to which the test was applied. Navigator-Technical and Officer Quality validities are also underestimated to some degree. Since admission to the School of Military Science-Officer against a pilot training quota requires a minimum qualifying score on all three AFOQT

composites, the assumptions underlying the usual corrections for range restriction could not be met. No corrections were attempted.

A series of multiple linear regression analyses were performed. These are summarized in Table 2. For the psychomotor tests, the X Axis, Y Axis, and Generated scores in each of the final two minutes of the test session were the predictors. Both psychomotor tests yielded significant multiple correlations with Graduation, but not with FTD. When predictor values, including Resets, from each minute of the entire test session were used, a correlation of .52 was obtained between Complex Coordination and Graduation. This correlation is significant beyond the .05 level. Over the same time interval, no significant correlations were obtained from Two-Hand Coordination. AFOQT subtests alone did not correlate significantly with either criterion, nor did a set of predictors including AFOQT subtests and scores from both psychomotor tests. This result is explained as a function of the large number of predictors in the regression system. The best single test for predicting UPT performance appears to be Complex Coordination.

Table 2. **Multiple Correlation of Psychomotor Tests and AFOQT against Two Pilot Training Criteria**
(N = 121)

Predictor Tests	Number of Predictors	Graduation	FTD
Two-Hand Coordination	6	.18	.20
Complex Coordination	6	.44*	.32
AFOQT	13	.37	32
Two-hand Coordination plus Complex Coordination	12	.46*	.38
Two-Hand Coordination plus Complex Coordination plus AFOQT	25	.56	.47

*Significant beyond .05 level.

The hypothesis was formulted that the psychomotor tests make no contribution to prediction of UPT Graduation in the context of the AFOQT. The test of the hypothesis yielded an F value of 1.96 and rejection of the hypothesis at the .05 level. The interpretation is that, had the psychomotor test scores been incorporated into the selection battery, the prediction of success in UPT would have been improved. This is the most important outcome of the study.

III. VALIDATION STUDY II

Subjects

The subjects for the second validation study consisted of 92 Officer trainees selected for pilot training. All were subsequently commissioned at the School of Military Science-Officer and were assigned to various bases for UPT. AFOQT scores were available for all subjects.

The Test

Although the second study was initiated before the results of the first were known, it was decided that Complex Coordination would be the sole psychomotor test to be validated. This decision was based on the availability of valid Z Axis scores for the second study.

The Predictors

All Complex Coordination predictors used in the first study were used again in the second. AFOQT scores were also used. However, the only readily available AFOQT scores were the operational composites in percentile form. The lengthy and expensive retrieval of AFOQT answer sheets to obtain subtests was not undertaken.

The Criteria

The criteria used in the first study were used again, and one additional criterion was defined.

This was designated FTD/SIE and consisted of all subjects who were either flying deficiency eliminees or self initiated eliminees from pilot training. Subjects in either elimination category were coded 1 and all others zero on this criterion. It was suspected that some student pilots who eliminate themselves are impending flying deficiency eliminees. Table 3 presents the criterion distribution of the subjects.

Table 3. **Distribution of Subjects by Criterion Category, Validation Study II**

Category	N
Flying Training Deficiency Elimination (FTD)	17
Self Initiated Elimination (SIE)	8
Manifestation of Apprehension Elimination	4
Medical Elimination	1
Total Elimination	30
Total Graduation	62
Total Subjects	92

Test Procedure

Subjects were tested in March and April 1971. Following the standardized instruction and practice period, Complex Coordination was administered five times with twenty minute intertrial intervals. For each administration, the error scores were integrated over 60 separate observation periods of five seconds duration. Hence, 60 values were available for each predictor on each trial of each subject.

Results

As in the first study, a series of multiple linear regression analyses were performed. In these analyses the X Axis and Y Axis scores were excluded from the predictor system. This decision was based on the finding that the mean correlation of the Generated score with each of these axis scores is .92, based on five observation periods of one minute. For purposes of the regression analyses, the 60 observation periods were combined to form five observation periods of one minute, and scores for each of the five minutes were used separately as predictors. The results for each five minute trial are shown in Table 4.

Table 4. **Multiple Correlation of Complex Coordination and AFOQT against Three Pilot Training Criteria**
(N = 92)

Predictor Tests	Number of Predictors	Trial	Graduation	FTD	FTD/SIE
Complex Coordination	15	1	.43	.50	.43
Complex Coordination plus AFOQT	20	1	.50	.56	.51
Complex Coordination	15	2	.56*	.43	.55*
Complex Coordination plus AFOQT	20	2	.62*	.50	.61*
Complex Coordination	15	3	.55*	.44	.55*
Complex Coordination plus AFOQT	20	3	.60*	.54	.61*
Complex Coordinatinn	15	4	.47	.41	.45
Complex Coordination plus AFOQT	20	4	.51	.47	.51
Complex Coordination	15	5	.51	.47	.49
Complex Coordination plus AFOQT	20	5	.57	.53	.55

*Significant beyond .05 level.

Significant multiple correlations were obtained on Trials 2 and 3, when the predictors were Complex Coordination alone or Complex Coordination plus AFOQT, and when the criterion was either Graduation or FTD/SIE. The AFOQT scores alone correlated .31 with each criterion. These correlations are not significant. Since the same selection standards apply to these subjects as to those in the first study, it is assumed that the AFOQT validities are again underestimated. In this case the underestimate is somewhat less severe, however, as indicated by a Pilot composite mean near 70.

The hypothesis was formulated that Complex Coordination scores make no contribution to prediction of graduation from UPT in the context of the AFOQT composite scores. The test of the hypothesis yielded an F value of 2.00 and rejection of the hypothesis beyond the .05 level. The implication is that inclusion of Complex Coordination scores in the selection system would improve the selection of successful student pilots.

Supplementary data on the zero order validities and intercorrelations of the variables in these studies are presented in Appendix A.

IV. CONCLUSIONS

Data from these two studies strongly suggest the pilot selection utility of the psychomotor tests, especially Complex Coordination. While it is difficult to assess the actual correlation between the various predictors and the criteria because of the complex ways in which the data are restricted in range, it is nevertheless clear that the addition of the psychomotor tests to the AFOQT can enhance the prediction of pilot training success. On this basis it is recommended that an operational version of the tests and their equipment be developed, and that a large scale validation of this operational version be undertaken.

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APPENDIX A: SUPPLEMENTARY TECHNICAL DATA

Tables A1 and A2 present correlations among X Axis, Y Axis, and Generated scores for each minute of testing time on Two-Hand Coordination and Complex Coordination, respectively. Data are based on the 121 subjects of Validation Study I who entered pilot training. All correlations are significant beyond the .01 level except one for Complex Coordination.

Table A1. **Correlation among X Axis, Y Axis, and Generated Scores, Two-Hand Coordination**
(N = 121)

	Generated Score	r X/Y
X Axis Error, Minute 1	.95*	.79*
X Axis Error, Minute 2	.98*	.89*
X Axis Error, Minute 3	.96*	.83*
X Axis Error, Minute 4	.97*	.86*
X Axis Error, Minute 5	.97*	.87*
Y Axis Error, Minute 1	.94*	
Y Axis Error, Minute 2	.97*	
Y Axis Error, Minute 3	.95*	
Y Axis Error, Minute 4	.95*	
Y Axis Error, Minute 5	.96*	

*Significant beyond .01 level.

Table A2. **Correlation among X Axis, Y Axis, and Generated Scores, Complex Coordination**
(N = 121)

	Generated Score	r X/Y
X Axis Error, Minute 1	.59*	.11
X Axis Error, Minute 2	.82*	.55*
X Axis Error, Minute 3	.79*	.59*
X Axis Error, Minute 4	.81*	.43*
X Axis Error, Minute 5	.78*	.42*
Y Axis Error, Minute 1	.85*	
Y Axis Error, Minute 2	.92*	
Y Axis Error, Minute 3	.91*	
Y Axis Error, Minute 4	.87*	
Y Axis Error, Minute 5	.88*	

*Significant beyond .01 level.

Tables A3, A4, and A5 present zero order validity data for the AFOQT and for each minute of performance on the two psychomotor tests. In Tables A4 and A5, negative correlations with Graduation indicate that graduates obtain lower error scores on the psychomotor tests than eliminees. Positive correlations with FTD indicate that eliminees make higher error scores than graduates. All these data are based on the 121 cases from Validation Study I.

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Table A3. **Zero Order Validity of AFOQT Subtests against Two Pilot Training Criteria**
(N = 121)

Variable	Graduation	FTD
Quantitative Aptitude	–.17	.13
Verbal Aptitude	–.16	.01
Biographical Inventory	.08	–.08
Scale Reading	–.10	–.06
Aerial Landmarks	–.08	.13
General Science	–.15	.09
Mechanical Information	–.04	.09
Mechanical Principles	–.02	.05
Pilot Biographical Inventory	.04	–.03
Aviation Information	–.16	.10
Visualization of Maneuvers	–.02	.00
Instrument Comprehension	.06	–.18*
Stick & Rudder Orientation	.12	.00

*Significant beyond .05 level.

Table A4. **Zero Order Validity of Two-Hand Coordination against Two Pilot Training Criteria**
(N = 121)

Variable	Graduation	FTD
X Axis Error, Minute 1	–.24*	.17
X Axis Error, Minute 2	–.19*	.11
X Axis Error, Minute 3	–.07	.04
X Axis Error, Minute 4	–.14	.13
X Axis Error, Minute 5	–.08	.50
Y Axis Error, Minute 1	–.17	.12
Y Axis Error, Minute 2	–.17	.09
Y Axis Error, Minute 3	–.04	–.03
Y Axis Error, Minute 4	–.07	.04
Y Axis Error, Minute 5	–.04	.06
Generated, Minute 1	–.22*	.15
Generated, Minute 2	–.19*	.10
Generated, Minute 3	–.06	.01
Generated, Minute 4	–.12	.10
Generated, Minute 5	–.06	.06

*Significant beyond .05 level.

Table A5. **Zero Order Validity of Complex Coordination against Two Pilot Training Criteria**
(N = 121)

Variable	Graduation	FTD
X Axis Error, Minute 1	–.15	.06
X Axis Error, Minute 2	–.32*	.14
X Axis Error, Minute 3	–.40*	.25*
X Axis Error, Minute 4	–.42*	.29*
X Axis Error, Minute 5	–.41*	.27*
Y Axis Error, Minute 1	–.16	.09
Y Axis Error, Minute 2	–.17	.06
Y Axis Error, Minute 3	–.24*	.10
Y Axis Error, Minute 4	–.20*	.15
Y Axis Error, Minute 5	–.16	.08
Resets, Minute 1	–.12	.07
Resets, Minute 2	–.20*	.09
Resets, Minute 3	–.22*	.10
Resets, Minute 4	–.16	.09
Resets, Minute 5	–.09	.05
Generated, Minute 1	–.21*	.11
Generated, Minute 2	–.27*	.12
Generated, Minute 3	–.34*	.19*
Generated, Minute 4	–.35*	.25*
Generated, Minute 5	–.31*	.20*

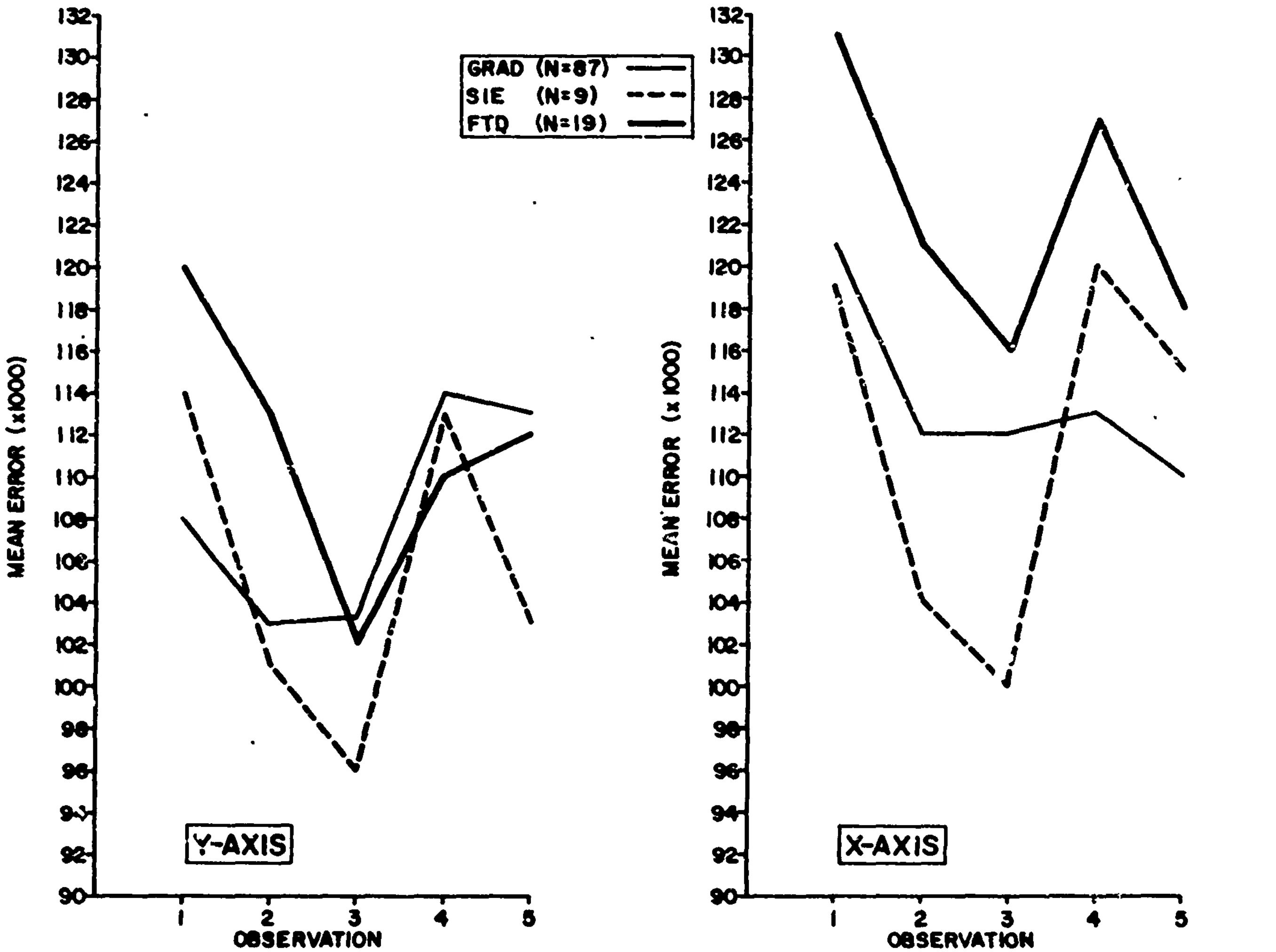
*Significant beyond .05 level.

A different kind of presentation of psychomotor validity data is seen in Figures A1 and A2. In both figures, the five observation points along the base line are minutes of the test during which the scores were derived. Figure A1 (Y-Axis and X-Axis) depicts mean performance on Two-Hand Coordination for three pilot training criterion groups. In two-Hand Coordination, performance measured on the X Axis corresponds to the subject's right hand, and performance on the Y Axis to the subject's left hand. Left hand performance show little difference between graduates and eliminees. Right hand performance, however, shows higher mean error scores in all observation periods for FTD eliminees than for graduates.

Figure A2 (Y-Axis and X-Axis) shows mean performance on the hand controlled task of Complex Coordination, using the same criterion groups. The mean error of the FTD criterion group on both axes is higher than for graduates. It was not expected that SIE performance would closely resemble performance by any other criterion group.

Tables A6 through A8 present intercorrelation and zero order validity data analogous to those in Tables A1 through A5. These data, however, are based on the 92 subjects in Validation Study II. The psychomotor data are derived only from Trials 2 and 3, and the validities are only for the Graduation and FTD/SIE criteria.

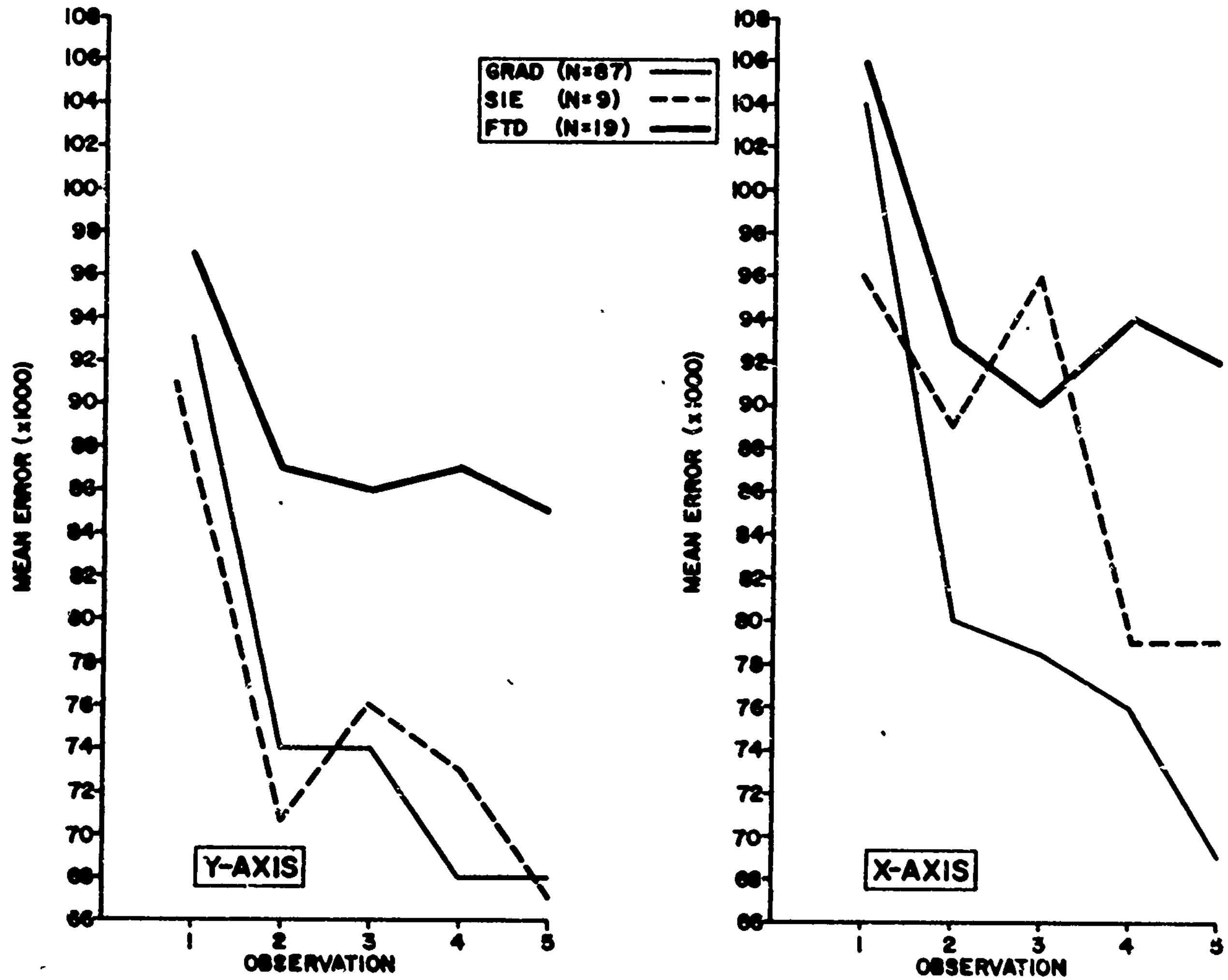
The original form of the psychomotor data for the second study was in terms of intervals of five seconds. It is of interest to observe the course of the mean error scores on the three axes within trials and across trials. Figure A3 contrasts Trials 1 and 5 in terms of error scores in their original intervals. Within each trial, the mean errors tend to decrease. Across trials, the mean X Axis and Y Axis errors become stabilized at about half their original values after 15 minutes of testing time.



MEAN ERROR OF LEFT HAND TRACKING (Y AXIS ERROR) ON TWO-HAND COORDINATION FOR THREE PILOT TRAINING CRITERION GROUPS

MEAN ERROR OF RIGHT HAND TRACKING (X AXIS ERROR) ON TWO-HAND COORDINATION FOR THREE PILOT TRAINING CRITERION GROUPS

Fig. A1. Mean error scores on two-hand coordination for three pilot training criterion groups.



MEAN Y AXIS ERROR OF HAND CONTROLLER PERFORMANCE ON COMPLEX COORDINATION FOR THREE PILOT TRAINING CRITERION GROUPS

MEAN X AXIS ERROR OF HAND CONTROLLER PERFORMANCE ON COMPLEX COORDINATION FOR THREE PILOT TRAINING CRITERION GROUPS

Fig. A2. Mean error scores on complex coordination for three pilot training criterion groups.

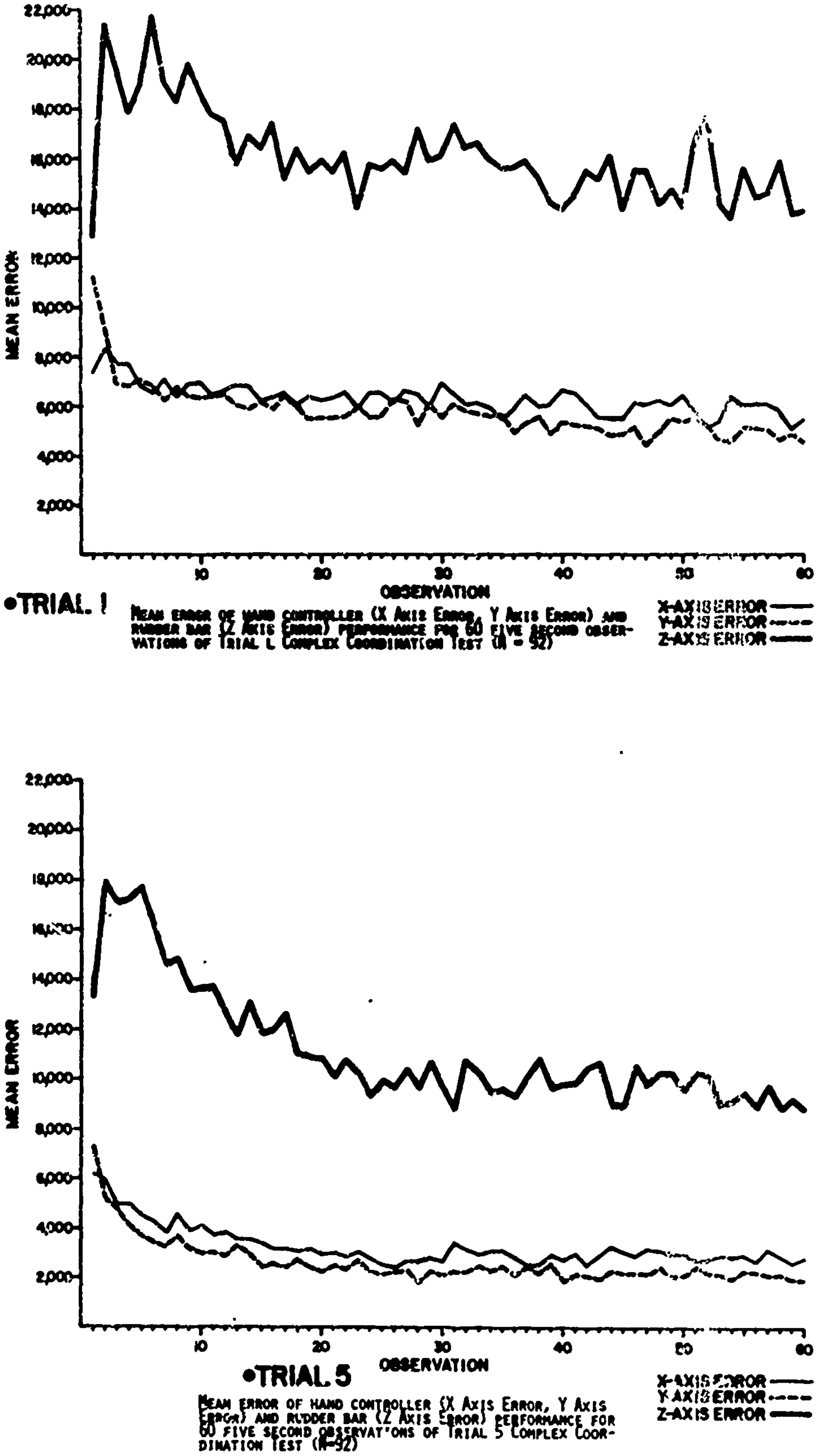


Fig. A3. **Mean error scores on complex coordination within and between trials 1 and 5.**

Table A6. **Correlation among X Axis, Y Axis, Z Axis, and Generated Scores, Complex Coordination**
(N = 92)

Variable	Trial 2 Generated Score	r X/Y	Trial 3 Generated Score	r X/Y
X Axis Error, Minute 1	.80*	.56*	.90*	.62*
X Axis Error, Minute 2	.85*	.56*	.93*	.74*
X Axis Error, Minute 3	.93*	.69*	.92*	.70*
X Axis Error, Minute 4	.96*	.74*	.88*	.62*
X Axis Error, Minute 5	.96*	.81*	.88*	.65*
Y Axis Error, Minute 1	.93*		.89*	
Y Axis Error, Minute 2	.90*		.93*	
Y Axis Error, Minute 3	.91*		.92*	
Y Axis Error, Minute 4	.89*		.91*	
Y Axis Error, Minute 5	.94*		.92*	
Z Axis Error, Minute 1	.21		.35*	
Z Axis Error, Minute 2	.49*		.53*	
Z Axis Error, Minute 3	.60*		.50*	
Z Axis Error, Minute 4	.66*		.54*	
Z Axis Error, Minute 5	.66*		.38*	

*Significant beyond .01 level.

Table A7. **Zero Order Validity of AFOQT Composites against Two Pilot Training Criteria**
(N = 92)

Variable	Graduation	FTD/SIII
Pilot	.10	–.05
Navigator-Technical	.01	.01
Officer Quality	–.06	.01
Verbal	–.12	.08
Quantitative	.16	–.20*

*Significant beyond .05 level.

Table A8. **Zero Order Validity of Complex Coordination against Two Pilot Training Criteria, Trial 2**
(N = 92)

Variable	Graduation	FTD/SIE
X Axis Error, Minute 1	.04	−.03
X Axis Error, Minute 2	−.29*	.28*
X Axis Error, Minute 3	−.22*	.23*
X Axis Error, Minute 4	−.19	.17
X Axis Error, Minute 5	−.24	.23*
Y Axis Error, Minute 1	−.15	.16
Y Axis Error, Minute 2	−.29*	.39*
Y Axis Error, Minute 3	−.21*	.30*
Y Axis Error, Minute 4	−.20*	.26*
Y Axis Error, Minute 5	−.27*	.32*
Z Axis Error, Minute 1	−.17	.13
Z Axis Error, Minute 2	−.27*	.26*
Z Axis Error, Minute 3	−.29*	.25*
Z Axis Error, Minute 4	−.20*	.15
Z Axis Error, Minute 5	−.27*	.22*
Resets, Minute 1	.06	−.08
Resets, Minute 2	−.23*	.18
Resets, Minute 3	−.20	.19
Resets, Minute 4	−.21*	.19
Resets, Minute 5	−.13	.10
Generated, Minute 1	−.07	.08
Generated, Minute 2	−.33*	.37*
Generated, Minute 3	−.24*	.28*
Generated, Minute 4	−.22*	.22*
Generated, Minute 5	−.27*	.29*

*Significant beyond .05 level.